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EDITORIAL

Are there line fences in science?

In the early days when the untilled prairies of the great American midland were broad and the tillers few, it was the rule to leave wide "turnrows" of virgin sod next the line fences. At a later stage these came to be almost the only virgin ground left, and they lingered here and there as the choicest residues of primitive fertility and native life. Since these in turn passed away, the tillage of each field has pressed hard on its neighbor's ground. It has been somewhat so in the scientific domain. The once neglected turnrows have become the fields that most invite culture. But this has been said before.

Notwithstanding this parallel, one is sometimes prompted to ask if there are indeed line fences in science. Have metes and bounds of ownership been set, at which one's work must stop? May the arbitrator say: To this point you may plow and plant, but no farther? Or is the tillage of the sciences reciprocal like the cropping of the cereals and the legumes? The more they are interplanted, within limits, the better for *both* crops, the Chinese say.

The question is concrete and takes sharp outline only through a concrete case. In citing such a case, matter may thereby get into print that is not in print, nor on the road to print; matter adjudged out of bounds, because it trespassed on others' fields.

It is permissible to cite such a case the more freely because the one in mind came at a time when bounds were shifting, when the chief parties in interest were absent or preoccupied. The case thus takes cover under the latitudinal functions of the important subordinate and the anonymous critic. It is moreover a case of friends among friends; it is not a scrap between hostiles. The case may not be material in itself, though it relates to an important inquiry, and lies at the threshold of an important enterprise. It would become important—important as a signal—if it were talismanic or were to become talismanic.

The evolution of the Bureau of Mines from a branch of the national Geological Survey is a historical event of a high order of importance in the progress of science as an aid to human welfare. It is worthy of note that the evolution is coincident with a critical stage in the progress of the chief inquiry to which the bureau has set itself, the protection of life against preventable disaster. The imperative nature of this inquiry has been impressed upon the world by the appalling disasters of 1907. That the main source of such disasters lies in the explosibility of coal dust rather than in explosions of pre-existent gases, and in the improper handling of explosives as the exciting agency, had already been recognized by critical investigators and had been set forth measurably in the literature of the subject, but it had not been accepted widely enough to be effective with those in whose hands the remedy rests. The further work to be done to attain practical success lay in more convincing evidence of the sources of disaster, in the discovery of effective preventives and in such education respecting these as is requisite to their effective adoption, a task at once of research, of invention, of demonstration, and of inculcation, in which each factor is imperative to the success of the whole.

When the shock of the disasters of the fall of 1907 awakened intense interest in the problem, the initial steps toward finding a method of forestalling such calamities had already been taken in America, following earlier steps of like nature in England, France, Belgium, and Germany; but as yet these had not reached sufficiently impressive demonstrations of the sources of disaster and were occupied with doubtful devices for prevention. The line of preventive measures which now seems the most promising had, indeed, been suggested many years earlier, but on limited grounds. It had failed to be adequately stimulative; indeed it seems to have fallen into practical oblivion. The American movement thus entered an open and urgent field with little more than the handicap of lesser experience and of a younger and busier community.

With a wise sense of the value of co-operative methods, the leader of the chief American movement chose for the investigation of the signal disasters in Pennsylvania and West Virginia an expert in explosives, an experienced inspector of mines, and a specialist in rock-gases. These worked co-operatively and yet in measurable independence. Less than two months after the inspection of the chief disasters, the specialist in rock-gases reported progress (February 15, 1908) of which the following is an extract:

Some Specially Suggestive Results

Another line of attack upon the problem which now looks as though it might lead to results of much importance was opened up last Tuesday when I made comparative analyses of the fresh coal, the uncharred dust, and the charred dust from a single room in No. 8 Mine at Monongah. In room No. 3 on the 3d right off the 2d north in Mine No. 8 we found the props heavily plastered with charred dust on the inby sides, while adhering to the outby sides of the same props was a thick deposit of uncharred dust. These dusts were in such quantities that cans were filled with samples of each which were collected with much care. At the same time a third can was filled with fresh coal taken from the rib a few feet away. This was ideal material for a comparative study. My analyses show the following results:

Fresh Coal

Moisture	1.24
Volatile matter	35.28
Fixed carbon	59.88
Ash	3.60
	100.00

Uncharred Dust

	First sample	*Second sample*
Moisture	2.30	2.34
Volatile matter	24.13	23.43
Fixed carbon	45.01	45.19
Ash	28.56	29.04
	100.00	100.00

Charred Dust

	First sample	*Second sample*
Moisture	1.13	1.20
Volatile matter	24.78	24.36
Fixed carbon	58.11	59.33
Ash	15.98	15.11
	100.00	100.00

An inspection of these analyses shows a striking difference in the percentage of ash. While a slight increase in the percentage of ash necessarily results from the loss of the volatile matter this accounts for but a small part of the great increase in the ash from these two dusts over that in the original coal. The difference is clearly due to the admixture of finely powdered shale swept up by the explosion. Small fragments of shale were readily recognized in the ash residue after the carbon had all been burned out. A fact which I believe to be of great significance is that *the uncharred dust contains nearly twice as much ash* (*shale dust*) *as the charred dust.* These dusts came from the opposite sides of the same identical props in a room into which the flames penetrated. Both dusts must have been subject to the explosion and yet they are very different in composition, the difference everywhere in the room depending upon which side of the prop the dust was located, the explosion having served as an admirable sorter. Now the explosion did not originate in this room, but advanced into it from the entry, and the outby sides of the props against which the dust was forcibly driven by the explosion are coated with dust containing nearly twice as much shale dust as is contained in the charred dust on the inby exposures of the props. The other and most significant difference is that the dust (on outby exposures) containing *28 per cent of ash and shale* is *not charred* while the dust (on inby exposures) which contains *only 15 per cent of ash and shale* is *charred* and has lost much more of its volatile hydrocarbons.

The differences in the charring of the dust and in the proportion of fine shale in the dust, I believe, are interrelated, one being the result of the other. The explanation, I think, is this: The dust is driven against the outby sides of a prop with much force but not with equal force, the shale particles by reason of their density being driven against it with greater force and hence more likely to stick. The portion which adheres on the outby side of the prop therefore contains more shale dust and less coal dust than an average sample. In the lee of the prop there is a reduced pressure, and an eddying current laps around against the inby side and permits more quiet adhesion. Now the specific gravity of this coal is 1.30 while that of average shale is about 2.60, which is just twice that of the coal. The coal dust is also likely to be finer than the particles of shale. Hence much of the heavier shale particles will be carried on past the post, while the weaker eddying current which touches the lee side will contain a much higher percentage of the lighter coal and less of the heavier shale. This explains the difference in the percentage of ash brought out so strikingly by the analyses.

The high percentage of shale in the dust by diluting the combustible dust and absorbing much of the heat necessary to inflame it has had such a dampening effect upon the combustion that the coal dust which was driven against the props directly was not charred. But in the lee of the props where the proportion of non-inflammable shale has been much reduced and the expulsion of the volatile combustibles is favored by the partial relief of pressure and the slower current, the dust yields up to the flame much more of its inflammable gases and becomes charred or even coked.

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> In addition to the theoretical and scientific interest attached to this new idea, I think this line promises much of practical value in the prevention of dust explosions, and these are the most disastrous of the mine explosions. If the presence of a certain proportion of shale dust mixed with the coal dust greatly reduces the explosibility of the latter, and reduces the volume of combustible gases which are fed to the flame so that the dust is not charred, it would seem that the addition of somewhat more pulverized shale would render the dust incapable of propagating an explosion. The force of the explosion itself gathered up 25 per cent of shale dust and if more shale were added artificially to the dust in the entries and rooms an explosion, even if once started, which would be much less likely, might snuff itself out before traveling throughout the whole mine. The addition of shale to the coal dust should be a comparatively simple matter. As soon as wet, by forming mud it should adhere to the coal dust and prevent the latter from becoming stirred up into the air for a long time after it had dried. Perhaps a very effective way to treat the dust would be to use a sort of shale douche made by mixing into the water used in sprinkling a mine a certain quantity of finely ground shale. While sprinkling with water alone does little good after the water has dried up, which takes place rapidly in winter, a shale douche by covering the coal dust with a thin coating of fine shale should keep the dust in a condition unfavorable for an explosion for some time after the water had dried. This being so, stronger ventilation could be used to remove the gas without the increased danger of a dust explosion.

A fuller report embracing further work was submitted later in the year. In the absence of the chief from the Washington office, this had an experience not altogether unknown in official practice. In the wisdom of the vicarious authority then regnant it passed beneath the blue pencils of unknown critics who found, among other things, that its furrows ran over the bounding line of the geo-chemical field and turned up some things thought to lie in the domain of engineers. It is not known that the critics were engineers and so naturally subject to sensitiveness as to the metes and bounds of the engineering field. The internal evidence implies that they were not engineers, at least not engineers acute to see what was latent in the geo-chemist's suggestions. At any rate the suggestions of the rock-gas expert were heroically blue-penciled. Their author, while arguing their legitimacy and their stimulative, directive, and educational value, made no appeal to the men higher up. It is not comfortable or diplomatic to make such an appeal when the merits or the good taste of one's products are in question, and so, as a compromise, or as a mitigation of the surrender, if you please, the emasculated section that laps from p. 55 over onto p. 56 of *Bulletin 383*, U.S. Geol. Survey, on "Explosive Mine Gases and Dusts with Special Reference to Explosions in the Monongah, Darr and Naomi Coal Mines," is all that found its way to the printer. Whether the intervention of unknown critics between governmental investigators and the public is wholesome or unwholesome no doubt depends on the competency of the criticisms, the spirit in which they are made, and the degree of insistence of the officer in charge as to how far the author must accept or must bow to them. In cases permissible to cite—and this seems to be one—the scientific public may be glad to know in concrete detail how the system works in actual practice where no unfriendly relations are presumed to enter to bias the course of procedure. The blue-penciled matter is as follows, and may be compared with the substitute just cited:

Practical Suggestions Springing from These Analyses

Final conclusions can, of course, only be reached after the most complete investigation possible, but meanwhile it is important to make all practical advances in the improvement of conditions on which so many lives depend, and every suggestion springing from the investigation is likely to have some value, both in mine control, and in further investigation. To this end, the suggestions of the foregoing observations in the mines, and in the laboratory, will be frankly stated, subject to modifications as further investigation and practical experience require; particularly as these observations and analyses give rise to a very definite suggestion as to a possible mode of reducing the liability of dusts to explode. This suggestion grows out of the striking difference which the analyses disclose between the charred, uncharred, and fresh coal dusts, with regard to the respective percentages of shale in them, particularly as shown on the opposite sides of the props in the Monongah mine. These differences indicate that the proportion of shale present in the dust exerted a marked influence upon the degree of coking, and the extent to which the dusts participated in the explosions. They suggest that the principle which seems to be involved, might be applied to effectually reduce the danger of a general explosion throughout a mine, if not to render such general explosion practically impossible. Even if a local explosion is inevitable at times from the sudden issue of gas, or from some other unavoidable incident, it is important to prevent the general extension of the explosion throughout the mine. In the cases in hand, this seems to have been a most serious phase of the disasters. If a moderate amount of fine shale mixed with the coal dust may have such a retarding effect upon the charring of the dust, as it appears to have had in the room studied at Monongah, it would seem that, by an addition of sufficient quantities of finely powdered shale, or earth material of similar kind, to the coal dust, we might reasonably expect that the latter would be rendered essentially non-explosive.

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Whatever may have been the immediate causes which precipitated these terrible disasters, the general, underlying cause of all of them seems to have been an explosive condition of the mine dusts, owing to the drying effect of strong ventilation at this season of the year. The strong ventilating currents were intended to dilute and remove the firedamp before it could accumulate in dangerous quantities, and to furnish good air to the miners. In both of these directions they were effective. But they dried the dusts, and therein seems to lie the source of greatest danger in the bituminous mines of this region. Simple gas explosions without the co-operation of dust could, certainly in the Monongah, and probably also in the Darr and Naomi mines, occur only as very localized explosions of pockets of gas, affecting only a very small portion of the mines. General mine explosions, due to gas alone, would seem impossible with the present ventilating systems of these mines in good working condition. The great extent and destructiveness of these recent explosions seem to have been due almost entirely to the coal dust.

Mutual Relations of Methods of Control

It is obvious that a first condition in the proper control of a coal mine is an effective system of ventilation, for this is the only safe remedy against the dangerous accumulation of methane and other explosive gases which may issue from the coal formation at unexpected times and threaten an explosion. Good ventilation is even more necessary for the health of the miners. It is indispensable. In the mines under investigation it appears to have been wholly adequate, but the investigation seems to show that ventilation itself has its dangers, and that these increase in proportion to the very effectiveness of this necessary measure. During the months in which cold air is forced in large quantities into warm mines, as is inevitable in the on-coming cold season following the summer warmth, the mines, as we have seen, are liable to become excessively dry and subject to dust explosions, even when they are fully protected against all serious gas explosions. Such general dust explosions may start from gas explosions that would, in themselves, be comparatively unimportant, or they may spring from entirely different causes, as defective blasting. The most serious problem, therefore, seems to be the development of practical devices by which the dangers of effective ventilation in the cool season may be reduced to the lowest possible terms. The chief practical suggestion of the foregoing investigation relates to this critical point of forestalling the incidental danger of an adequate system of ventilation which is, in itself, an absolute necessity to good mining conditions.

The chief precaution which has been taken against dust explosions in the past has been to sprinkle the entries with water, but sprinkling the mine with ordinary water is effective only so long as the dust is kept in a moist condition, which is not long in the winter time. This method seems to have been ineffective in these exploded mines because the sprinkling did not reach the various points in the mines until long after the water of the previous wetting had evaporated and the dust become dry. Water, in order to constitute any real safeguard by itself, must be sprayed over all parts of a mine at short intervals. This involves much labor, and, in time, expense. It also has the great disadvantage of weakening the roof in certain mines and increasing the likelihood of rock falls which, after all, cause more fatalities than explosions. Turning exhaust steam into the intake air, while it helps to raise the temperature of the air and supply it with moisture, also favors rock falls, and in addition is said to rot the mine timbers.

A suggestion which has been made is to sprinkle with a solution of calcium chloride instead of pure water. Calcium chloride has such a strong affinity for water that it absorbs moisture rapidly from the air, and a solution of it could never be evaporated dry in ordinary atmospheric air. Dust, wet with a strong solution of calcium chloride should remain damp for a long time, even though the circulating air were in the proper condition to exert a strong drying influence upon the mine. Treated in this way, the dust might be kept so thoroughly dampened that the chances of a dust explosion would be greatly reduced. The expense of using this solution need not be very great, for calcium chloride can be cheaply manufactured. However, with the mine wet with a strong solution of calcium chloride, it is possible that the miners, by constantly coming in contact with it, might suffer both from the rotting of their clothing and possibly an injurious effect upon their health.

Arising from the studies of the dust at Monongah are the suggestions that the explosibility of coal dust may be much reduced by mixing with it finely pulverized shale. One of the most obvious ways to mix this non-combustible matter with the coal dust on the ribs and timbers of a mine is to stir finely ground shale, or similar earthy material, into the water with which the mine is sprinkled. It is clear that means can be devised by which it will be possible to keep shale, mud, or lime constantly stirred up in the water during the operation of sprinkling. When the water dries it must leave behind the mineral matter held in suspension and thus form a coating upon the walls. If this operation be frequently repeated, the amount of non-combustible impurity mixed with, and adherent to, the dust on the ribs must steadily increase and render the coal dust less and less capable of feeding and carrying an explosion flame, so long as the dusts remain mixed.

One of the greatest possible advantages which may be claimed for the use of shale, earth, or lime, in the water, is based upon the property of mud to adhere to that with which it comes in contact, and to hold together, even after it has become completely dry. By adhering to the particles of fine coal, this dust would be much less readily stirred into the air in everyday mining operations. The mud, clay, shale, or whitewash coating upon the ribs and props must bind the coal dust particles to the coal or timbers with sufficient tenacity to prevent them from being swept up by the ordinary currents of air passing through the entries. Because of greater adhesiveness, mud or soft, clayey shale should be preferable to the more indurated slates, while whitewash has some properties which make it superior to either. Perhaps a mixture of lime and shale, or clay, would prove preferable to either of the constituents used alone.

Since the effects of sprinkling with this shale douche or mixture of earthy material and whitewash last after the water has evaporated, it would not be necessary to sprinkle the entries so often as when water alone is used, for this property of non-combustible shale to diminish the inflammability of the coal dust is not dependent upon the presence of a continuous supply of moisture in the mines. Unlike sprinkling with water alone, if the dust is once made comparatively harmless by the admixture of a very large amount of very fine shale, or similar adhesive mineral matter, it remains so (even though the mine be completely dried out) until an additional amount of coal dust has accumulated, or the dusts in some way become partially separated. Whether the dust be wet or dry becomes less important, though wetness constitutes, of course, an additional safeguard. This manner of treatment implies a certain amount of spraying with water, but a far less amount than the ordinary sprinkling method. Hence the chief dangers of increased rock falls, and other drawbacks of the common water method might be largely escaped.

The treatment of the entry floors is simpler than that of the walls. The pavement may be sprinkled with the same preparation as the ribs and timbers, but it would probably be better to grind the shale to a fine powder outside of the mines, run it underground in the mine cars and spread the dust uniformly over the pavement, throughout the entries. The coal dust on the floor would then either be mixed with, or buried beneath, several times its weight of mineral substance. If sufficient shale be spread along the entries and fairly tight mine cars are used, the shale or earth on the pavement probably would not need to be renewed for a considerable length of time.

Whether shale dust on the entry floors alone, is competent to check a dust explosion once under way, while the fine coal dust, unmixed with shale or whitewash, is present upon the ribs and timbers, can only be told by trial experiment. That an enormous amount of dust and fine particles of coal is swept along the entries during an explosion was strongly brought out by an inspection of the coal ribs in these exploded mines. Very generally throughout these mines, except where the mechanical force of the explosion was greatly reduced, the exposed corners and protuberances of the coal were rounded and often highly polished on exposures facing the source of the explosion, while nearly always angular and dull on the corresponding exposures facing from the blast. This rounding indicated much abrasion and wear, and resembled somewhat the familiar polishing of bowlders and pebbles by the sand blasts in arid regions. As this smoothing of corners and burnishing of exposed surfaces was all accomplished in the very short length of time which the explosion occupied in traveling through a given section of an entry, the mass of dust and particles of coal carried along by the blast must have been very great. If such a mass of fine, non-combustible shale dust be swept up from the pavement of an entry which has previously been thickly covered with this material, it is possible that the whole explosion might be stopped by this influence alone.

Because the principles of the shale treatment apply to either wet or dry dusts, it would seem that, by this means, the chief danger of over-ventilation during the cold season of the year might be greatly lessened, if not eliminated. With the coal dust thus treated, the gas in the mines could then safely be removed by the vigorous ventilation which is required to remove the firedamp and to supply the miners with fresh air.

The introduction of shale, clay, or whitewash should be free from any injurious effects, either upon the mine or the miners at work. As these substances do not begrime men to anything like the degree that coal dust does, the conditions in the workings should be improved rather than otherwise, from the miners' standpoint. Whitewash, by rapidly absorbing carbon dioxide from the mine air, should have a favorable influence upon the hygienic conditions of a mine. While sprinkling a mine continually with water weakens the roof and increases the number of rock falls, whitewashed walls, by greatly enhancing the illumination of an entry, make it easier to detect dangerous conditions at the roof.

The introduction of pulverized shale, or other earthy material into a mine, thus increasing the quantity of fine dust in the workings, may possibly seem to be increasing one source of danger while reducing another. The experiments of Sir Frederick Abel have shown that certain mixtures of methane and air which passed a naked flame without any symptom of ignition were inflamed when particles of fine, light, non-combustible powder, such as calcined magnesia, were suspended in the gas.[1]

While these gas mixtures were such as could not be exploded by a naked flame they were, nevertheless, not far below the explosive limit. Professor Abel further qualified the statement of his conclusions in this way: "The power of favoring the ignition of mixtures of firedamp and air was not exhibited by some other powders similar in fineness to the latter, but different in structure and density from this and one or two other non-combustible dusts which may be called active; even different samples of magnesia, differing somewhat in likeness from each other, appeared to possess the activity in different degree."

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[1] Sir Frederick Abel, *Proc. Roy. Inst.*, X (1882), 88–113.

Only certain dusts, therefore, possess this property which Professor Abel believed to be due to a contact, or catalytic, action upon the gas mixtures, analogous to that manifested by finely divided platinum toward certain gases.

Just how much influence shale dust could exert in this direction has not been determined. It is possible that a mixture of firedamp and air, very close to the lower limit of inflammability, but still not sufficiently rich in methane to be ignited by a flame, might become ignited from the flame when a certain amount of very fine, dry shale dust was stirred into it. But it is probable that only a gas mixture which was very close to the limit of inflammability could become ignited under these conditions. It is also to be remembered that whatever influence of this sort the shale might have, would be possessed, in a far greater degree, by even a very small amount of coal dust in the air. In mines where there is always coal dust present in varying quantities, the possible activity of fine shale in facilitating an explosion should be negligible in comparison to that of the coal dust. Furthermore, the heavier shale, or earthy material, by adhering to the lighter coal dust, tends to keep it out of the air. Finally, the phenomena of typical dust explosions in which the flame, because of the great abundance or excess of combustible matter furnished by the coal dust (even in non-gassy mines), seeks the fresh intake air indicate that these dust explosions are very different from what would be produced by the ignition of mixtures of firedamp and air rendered explosive by the catalytic action of the dust, but, instead, must be largely a matter of the rapid combustion of the readily inflammable hydrocarbons of the dust itself.

Another objection which might be urged is that the shale and coal dusts may become partially separated owing to their difference in specific gravity. Ordinary air currents can pick up light coal dust more easily than denser shale, or clay, particles. As a result, whatever dust might be stirred into the air would be likely to contain a higher proportion of coal than that on the walls or floors. But still there should be much less coal dust in the air, in absolute mass, than if the shale treatment had not been applied, since the mud, because of its adhesive properties, must hold down much fine coal dust which otherwise might easily become floating in the air. However, when an explosion is once started and under headway, it must sweep up nearly all the available dust, coal and shale alike, and hence it would be the character of this mixed dust which would determine the further progress of the explosion.

The foregoing discussion of suggestive preventive measures which were the direct outcome of observational and experimental data have been extended considerably upon theoretical grounds in order to bring out, in a more comprehensive manner, what advantages and disadvantages might be expected to accompany the use of finely pulverized shale, clay, or other earthy material in the mines. The discussion is intended merely to open up, in a preliminary suggestive way, a field for investigation which appears to show some promise of yielding results.

The emasculated substitute for the foregoing discussion that alone found place in *Bulletin 383*, a page and a fraction in extent, seems to have been so far robbed of effective suggestiveness that it did not call forth even a mention by the author of the historical statement of investigations bearing on the use of stone dust as a deterrent in coal dust explosions given the public in *Bulletin 425* recently issued under the same auspices as *Bulletin 383*, though the unemasculated portions of the latter found suitable recognition, as did also and naturally the important advances made in 1908 and 1909 in France, England, and other European countries in this promising line of preventive endeavor, stimulated apparently, in part at least, by the American disasters.

It is of minor consequence that the bureau thus loses a part of its own legitimate prestige in the new movement and falls into line behind rather than abreast of its European coworkers, for such relative position is mainly a matter of national pride, and this is no doubt a form of vanity, however stimulative and wholesome it may be; but it is not permissible to dismiss so lightly the more vital fact that an aid toward that laborious education which is prerequisite to a final practical success was thrown away by cutting out or cutting down to an ineffectual minimum these suggestions that sprang from one of the main lines of approach attempted, even though the suggestions might be thought to overlap ground lying more directly in the path of some other line of approach. The prerequisite educational work is at once scientific, technical, practical, and popular, and will inevitably be slow because of the human inertia to be overcome. It involves the growth of scientific opinion, usually cautious and hesitant, the growth of public opinion, usually inert and sluggish, the working assent of laborers on whom new restraints must be laid, the concurrence of managers on whom new cares are to be thrown, the co-operation of owners on whom new expenses are to be imposed, the enlightenment of legislators of whom new enactments are to be required, and the inspiration of public officials on whom new duties are to be placed. If the psychological moment for such education in any of its phases is at hand, by reason of the shock of appalling disasters, is it wise to question too closely the nativity or the caste of the schoolmaster? May he not, after all, have rights on other than his native sod and have proper functions outside the caste limits to which certain ancestral conventions might be disposed to confine him?

T. C. C.